Overview of Integrated Science Assessment for Oxides of Nitrogen, Oxides of Sulfur, and Particulate Matter – Ecological Criteria (Final)

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Disclaimer

This presentation is based on information provided in the Final Integrated Science Assessment for Oxides of Nitrogen, Oxides of Sulfur and Particulate Matter-Ecological Criteria. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

NO_XSO_XPM Ecology ISA Team

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Background

Criteria Pollutants

- The Clean Air Act requires EPA to set National Ambient Air Quality Standards (NAAQS)
  - Primary Standards are based on human health
  - Secondary Standards are welfare based (ecology included in welfare category)

What is an Integrated Science Assessment (ISA)?

- A comprehensive evaluation and synthesis of the policy-relevant science
  - "useful in indicating the kind and extent of all identifiable effects on public health or welfare which may be expected from the presence of [a] pollutant in the ambient air," as described in Section 108 of the Clean Air Act
- Provides the scientific underpinning for NAAQS review

The 2020 Oxides of Nitrogen, Oxides of Sulfur and Particulate Matter (NOxSOxPM) ISA

- Synthesized the most policy relevant science and updates the 2008 NOxSOx ISA
- Emphasized deposition-related science (in addition to concentration-related science)
- Final released in October 2020

Chemical species included in the criteria pollutant categories

Oxides of nitrogen

- Total oxidized nitrogen (NO_Y) includes the transformation products from emissions of oxides of nitrogen (e.g., nitric acid and particulate nitrate)
- The term NOx is traditionally limited to the sum of NO + NO_2 only

Oxides of sulfur

- Total oxidized sulfur (SO_X) includes particulate sulfate (SO_4^{2-}) and sulfur dioxide (SO_2)

Particulate matter (PM)

- Nitrogen and sulfur components of PM include nitrate (NO_3^-), SO_4^{2-}, ammonium (NH_4^+)
- Other components of PM by size fraction include metals, minerals (inorganic dust), and organic and elemental carbon.

Summary of Current NAAQS

Secondary NAAQS for oxides of nitrogen and oxides of sulfur

- Current indicators are NO_2 and SO_2 (for criteria pollutant category oxides of nitrogen and oxides of sulfur, respectively)
- Set to protect against injury to vegetation

Criteria Pollutants	Averaging Time	Level	Form
Nitrogen Dioxide	1 year	53 ppb	Annual Mean
Sulfur Dioxide	3 hours	0.5 ppm	Not to be exceeded more than once a year

- No standards to provide protection against potentially adverse *deposition*-related effects

Secondary NAAQS for particulate matter

- Concentration-based standards of size fractions ($PM_{2.5}$ and PM_{10}) set to protect against ecological effects, visibility impairment, effects on materials, and climate impacts

Deposition effects are the greatest concern

Final NOxSOxPM ISA: 3010 citations (literature cutoff date May 2017, unless reference provided by CASAC) synthesized in 1768 pages

Gas phase: Little evidence is available to inform whether current monitored concentrations of gas-phase NO_Y and SO_X are high enough to injure vegetation

Deposition (multi-pollutant): There is substantial evidence on the ecological effects deposition at current levels

- It is clear that NO_Y, SO_X, and PM contribute substantially to total N and S deposition.
- PM of interest includes: NO_3^-, SO_4^{2-}, NH_4^+
- Three main categories of deposition effects:
  - Acidifying deposition [NO_Y + SO_X + PM]= Acidification
  - N deposition effects [NO_Y + PM (NH_4^+ + NO_3^-)] = N enrichment/eutrophication
  - S deposition effects [SO_X/PM (SO_4^{2-})] = Sulfide toxicity and Hg Methylation

Causality Determination Framework

Consistent and transparent basis to evaluate the causal nature of air pollution-related health or welfare effects within an ISA

Based on evaluation and synthesis of evidence from across scientific disciplines

Weight of evidence for causal determination

- **Causal relationship**
- **Likely to be a causal relationship**
- **Suggestive of a causal relationship**
- **Inadequate to infer a causal relationship**
- **Not likely to be a causal relationship**

https://www.nationalacademies.org/our-work/assessing-causality-from-a-multidisciplinary-evidence-base-for-national-ambient-air-quality-standards

Ecological Effects Occur across Biological Scales of Organization

NOx SOx PM Integrated Science Assessment for Ecological Effects*

			Indicator	Gases ǂ	Nitrogen Deposition				Sulfur Deposition				Nitrogen and Sulfur Deposition	
			Class of Pollutant Effect	Direct Phytotoxic	N-enrichment/Eutrophication				Sulfide Toxicity		Mercury Methylation		Acidification	
			Ecosystem	Terrestrial	Terrestrial	Wetland	Fresh Water	Estuary	Wetland	Fresh Water	Wetland	Fresh Water	Terrestrial	Fresh Water
Scale of Ecological Response	Ecosystem	Productivity												
	Community	Biodiversity												
	Population / Individual	Growth rate												
	Individual	Physiological alteration, stress or injury												
	Geochemistry	Soil or sediment chemistry												
		Surface water chemistry												

Causality framework

Causal | Likely causal | Suggestive | Inadequate | Not likely | Not evaluated in causal framework

* A causal relationship is likely to exist between deposition of PM and a variety of effects on individual organisms and ecosystems, based on information from the previous review and limited new findings in this review

ǂ Includes: NO, NO_2, HNO_3, SO_2, and PAN

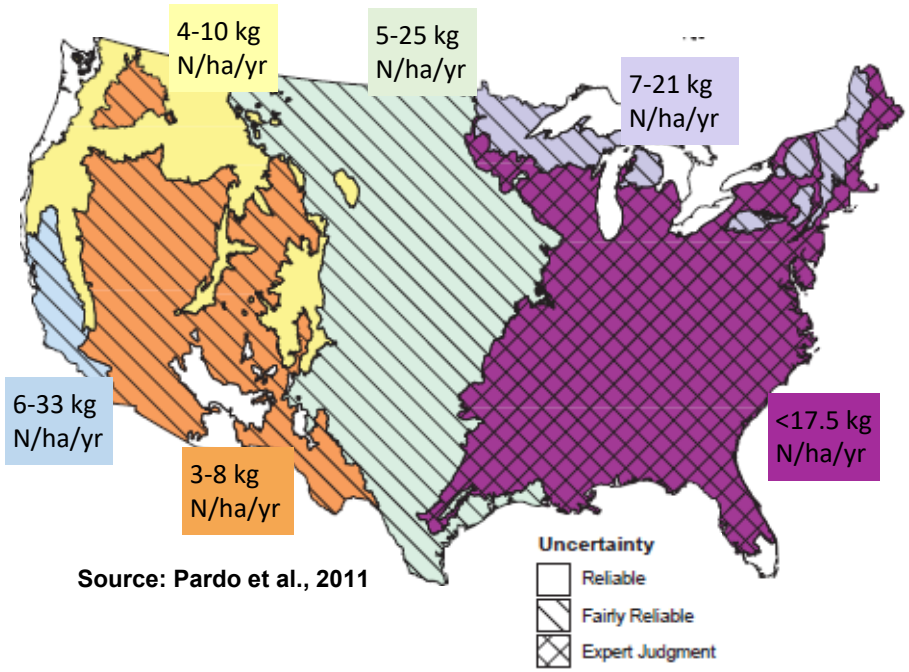
= new causal determinations since 2008

Does the ISA include Critical Loads (or Critical Levels)?

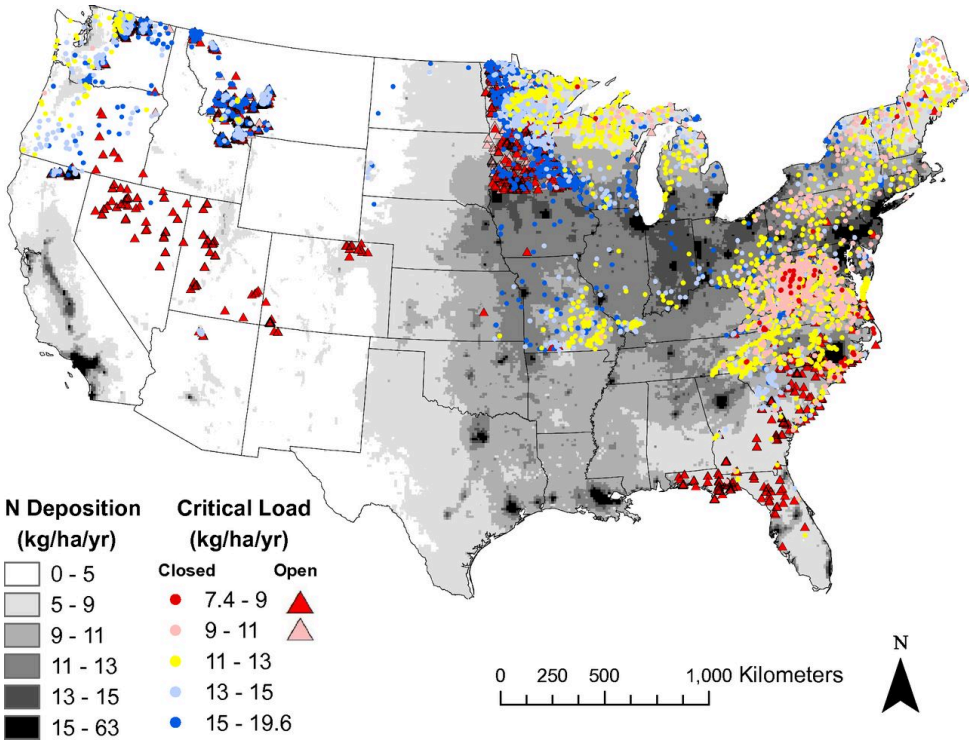
- The ISA cites all peer-reviewed literature on critical loads (empirical and modeled) and provides an overview of
  - The deposition levels associated with CLs in the US
  - The adversity of those effects as described in the publication
  - Terrestrial, wetland and surface waters CLs are included
  - Geographic/Spatial evaluations summarized from literature
- The ISA reports strength of studies
- The ISA does not make judgments about new critical loads

Visualizations from the Literature: Nitrogen Critical Loads for Herbaceous Plant Biodiversity

Critical load estimates for the onset of species loss from USDA-FS (below) and an update in 2016 (right)

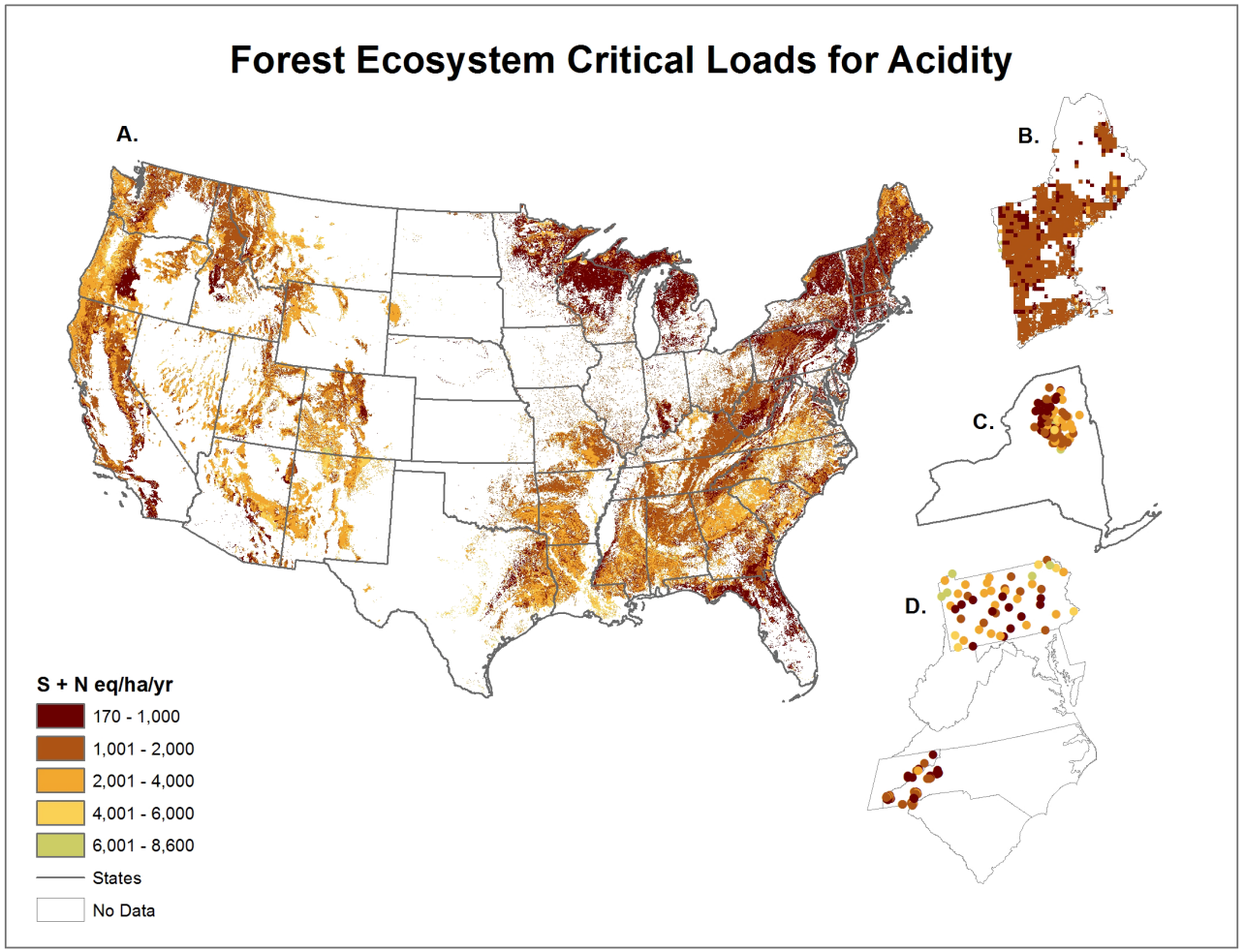


Source: Pardo et al., 2011



Source: Simkin et al. 2016;113:4086-4091

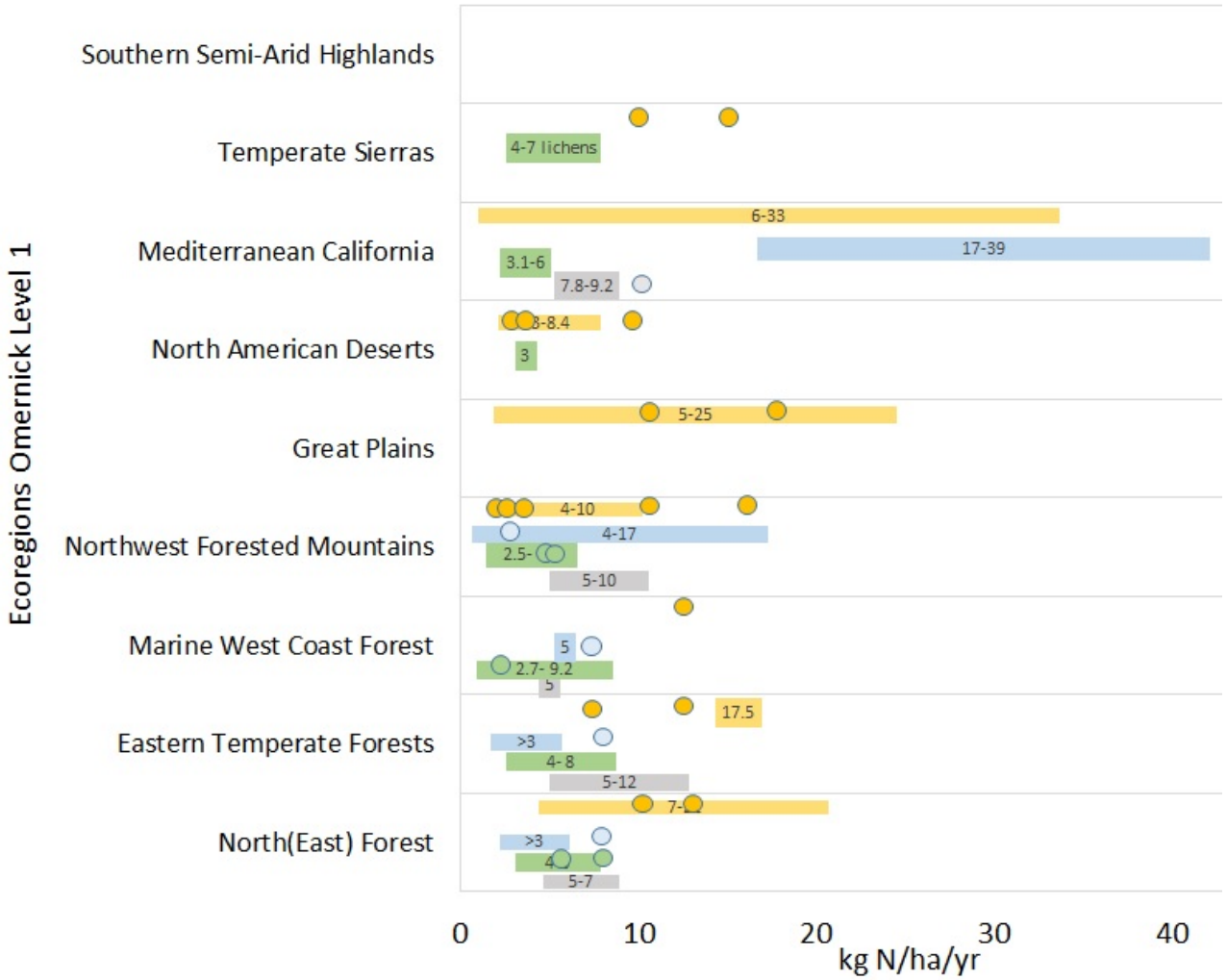
Terrestrial Acidification National Sensitivity



Source: National Critical Load Database 2015

Critical loads (as H^+ equivalents) for soil indicator (BC:Al and Ca:Al) values that link to adverse effects on plants.

New Visualizations: Nitrogen Critical Loads for U.S. Ecoregions as of 2017



Bars= critical loads (CL) developed by USDA-FS (Pardo et al. 2011)

Circles= new CLs published since 2011

Gold =herbaceous plants and shrubs

Green=lichens

Grey=mycorrhizae

Blue=Tree

The onset of most effects is below 10 kg/ha/yr

Main messages

Current NO_2 & SO_2 Secondary Standards are based on foliar injury:

- No new evidence that foliar injury occurs at current concentrations in U.S.

N enrichment from atmospheric **deposition** alters many ecosystems:

- National N deposition rates have been fairly constant; decreasing NO_Y deposition offset by increased NH_x deposition
- New quantitative evidence that *current rates* of N deposition cause:
  - Decreases in lichen biodiversity and herbaceous plant biodiversity
  - Positive and negative effects on tree growth and mortality
  - Increases in algal growth, loss of sensitive aquatic species
- New thresholds of deposition (critical loads) are available for biological effects
- Wetlands, estuaries, and most surface waters are less sensitive to N deposition because they also receive N inputs from agricultural and urban sources

Acidification from N & S **deposition** continues to affect ecosystems:

- Negative effects on fish, plants, plankton are well-documented
- S deposition has greatly declined over the past 30 years; driving decreases in total acidifying deposition observed in the East
- Some geochemical recovery has been documented in Northeast

S enrichment from **deposition** alters aquatic and wetland ecosystems:

- New evidence that S deposition causes increases in sulfide toxicity and mercury methylation

Final ISA for NOxSOxPM- Ecological Criteria may be found here:

- https://www.epa.gov/isa/integrated-science-assessment-isa-oxides-nitrogen-oxides-sulfur-and-particulate-matter

How is the information in the ISA used in the NAAQS review?

- The NOxSOxPM ISA provides a critical assessment of the latest available scientific information upon which the NAAQS are to be based
- The NOxSOxPM Risk and Exposure Assessment (REA) Planning Document
  - "The purpose of the REA in a secondary standards review is to estimate risk and exposure to public welfare associated with the current standards and, if appropriate, evaluate potential improvements in public welfare that could be achieved from meeting potential alternate standard(s)."
  - The REA Plan is publicly available
    - https://yosemite.epa.gov/sab/sabproduct.nsf//0/340096995904CF1085258083 0071FEA8/$File/REA+Plan+Final+Draft+080618.pdf
    - 9/5-6/2018 REA plan was reviewed by CASAC at a public meeting
    - The plan outlines the assessment approach and potential new (not published in the literature) policy-relevant quantitative analyses
- The NOxSOxPM Policy Assessment (PA)
  - "evaluates the policy implications of the information contained in the ISA and of any policy-relevant quantitative analyses, such as a quantitative REA, that were performed for the review"

Thoughts on NPS Seminar Questions

- how can a park/forest integrate their local data to better understand the risk of impacts?
- is there data that a park might have that could advance your research?
  - Any peer-reviewed publications on the effects of NOy, SOx or PM are of interest
  - Discussion and quantification of the adversity of the ecological effects
  - Quantification of atmospheric concentration-deposition-ecological effect
- what additional research could parks pursue to better understand the presented responses?